NUHEP-TH-96-5

COMPARATIVE STUDY OF THE HADRONIC PRODUCTION OF B_c MESONS*

ROBERT J. OAKES

Department of Physics and Astronomy,

Northwestern University, Evanston, IL 60208, USA

Abstract

The full order α_s^4 perturbative QCD calculation of the production of B_c mesons at the Tevatron is compared with the fragmentation approximation. The non-fragmentation diagrams, in which two or more quarks and/or gluons can simultaneously be nearly on-shell, are important unless $P_T \gg M_{B_c}$.

I. INTRODUCTION

Hadronic production of B_c and B_c^* mesons is of considerable, current interest. At hadronic colliders, the dominant subprocess is $g + g \to B_c(B_c^*) + b + \bar{c}$ and 36 Feynman diagrams contribute in the lowest order, α_s^4. At sufficiently large B_c or B_c^* transverse momentum, P_T, the fragmentation approximation dominates. This process is ideal for quantitatively comparing the fragmentation approximation and the full order α_s^4 calculation, since both can be reliably calculated. We have shown [1] that the fragmentation approximation

*Presented at the American Physical Sociaty, Division of Particles and Fields Meeting, 10-15 August 1996.

and the full order α_s^4 calculation agree when and only when $P_T \gg M_{B_c}$. At small P_T the non-fragmentation contributions become important since, when the B_c or B_c^* is nearly collinear with the initial partons, it is possible for two or more quarks and/or gluons in the subprocesses to simultaneously be nearly on-mass-shell.

II. CALCULATIONS AND RESULTS

Figure 1 shows the P_T distributions for the process $p+\bar{p} \to B_c(B_c^*)+X$ at the Fermilab Tevatron energy $\sqrt{s} = 1.8$ TeV with the rapidity cut $|Y| < 1.5$. Remarkably, the B_c meson P_T distributions agree rather well, even for P_T as small as about 5 GeV, while for the B_c^* meson the distributions differ by $50-70\%$ over a much larger range of P_T, leaving the comparison inconclusive.

The P_T distributions for the subprocess $g(k_1) + g(k_2) \to B_c(P) + b(q_2) + \bar{c}(q_1)$, which are shown in Fig. 2, are somewhat more revealing. The distributions agree reasonable well when P_T is larger than about 30 GeV for the B_c meson and about 40 GeV for the B_c^* meson. Consequently, the P_T distributions alone are not decisive and, as will be shown, can even be misleading.

It is more insightful to examine the distributions in $z = 2(k_1 + k_2) \cdot P/\hat{s}$, which is simply twice the fraction of the total energy carried by the B_c or B_c^* in the subprocess center of mass. Note that z is experimentally measurable, at least in principle. Figure 3 shows the z distributions, $C(z)$, for the process $p + \bar{p} \to B_c(B_c^*) + X$ for $\sqrt{s} = 1.8$ TeV, $|Y| < 1.5$, and $P_T > 10$ GeV. The distribution [1] $C(z) \equiv d\sigma/dz$. From Fig. 3 it is clear that for the B_c the fragmentation approximation underestimates the full order α_s^4 calculation for small z and overestimates it for large z. This results in a cancelation in the B_c P_T distribution, Fig. 1, fortuitously causing the fragmentation approximation to agree with the full order α_s^4 calculation down to quite small values of P_T.

However, for the B_c^* the fragmentation calculation underestimates the full order α_s^4 calculation at all values of z and no fortuitous cancelation occurs, as for the B_c.

The relative importance of the fragmentation and non-fragmentation contributions is even more clearly evident in the P_T distributions for the subprocess $g + g \to B_c(B_c^*) + b + \bar{c}$ at very large $\sqrt{\hat{s}}$, as is shown in Fig. 4. Clearly, the non-fragmentation contributions dominate at small P_T, where two or more quarks and/or gluons can simultaneously be very nearly on-mass-shell in the subprocess.

III. CONCLUSIONS

We have compared the full order α_s^4 perturbative QCD calculation of the production of B_c and B_c^* mesons at the Fermilab Tevatron with the fragmentation approximation. There are Feynman diagrams present in the full order α_s^4 matrix element in which *two or more* quarks and/or gluons can simultaneously be nearly on-mass-shell, and these dominate over the fragmentation approximation at small P_T. The fragmentation approximation dominates when and only when $P_T \gg M_{B_c}$.

ACKNOWLEDGMENTS

This research was done in collaboration with Chao-Hsi Chang and Yu-Qi Chen and is presented in greater detail in reference 1, where references to previous work can also be found. We acknowledge the support of the U.S. Department of Energy, Division of High Energy Physics, under Grant DE-FG02-91-ER40684 and the National Nature Science Foundation of China.

REFERENCES

[1] C.H. Chang, Y.Q. Chen, and R.J. Oakes, Phys. Rev. D, in press.

FIGURES

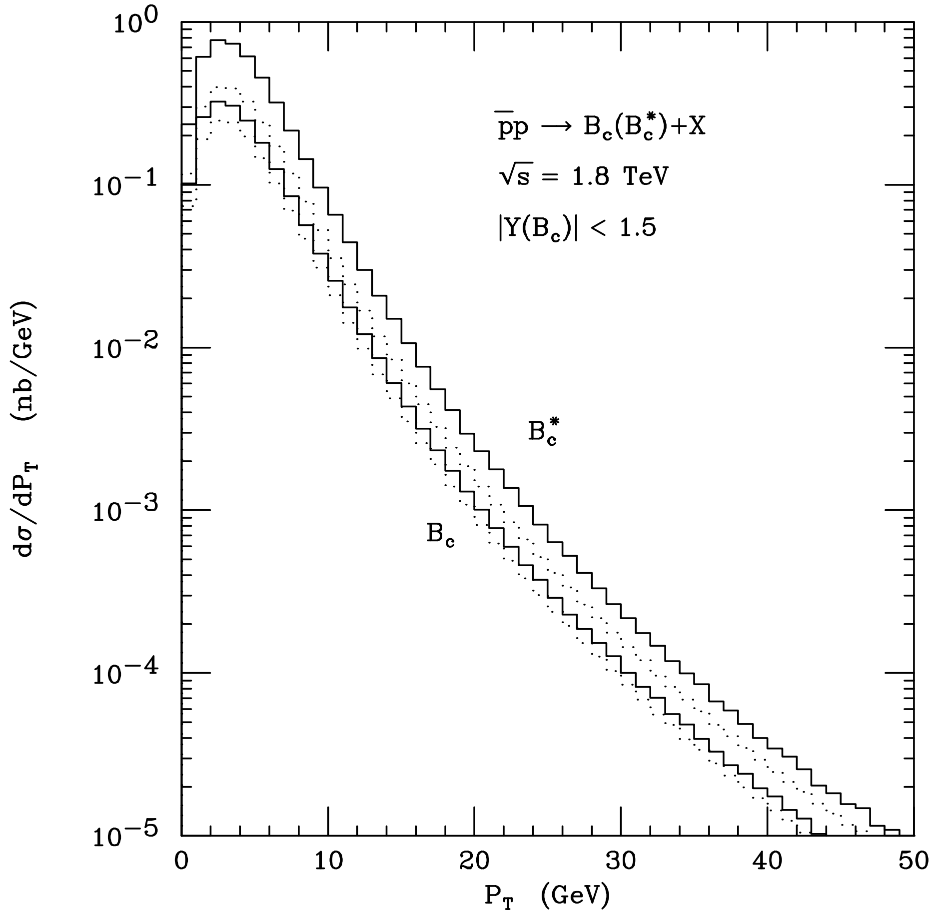

Fig. 1 The P_T distributions for B_c and B_c^* meson production at the Tevatron energy $\sqrt{s} = 1.8$ TeV. The solid and the doted lines correspond to the full α_s^4 calculation and the fragmentation approximation, respectively.

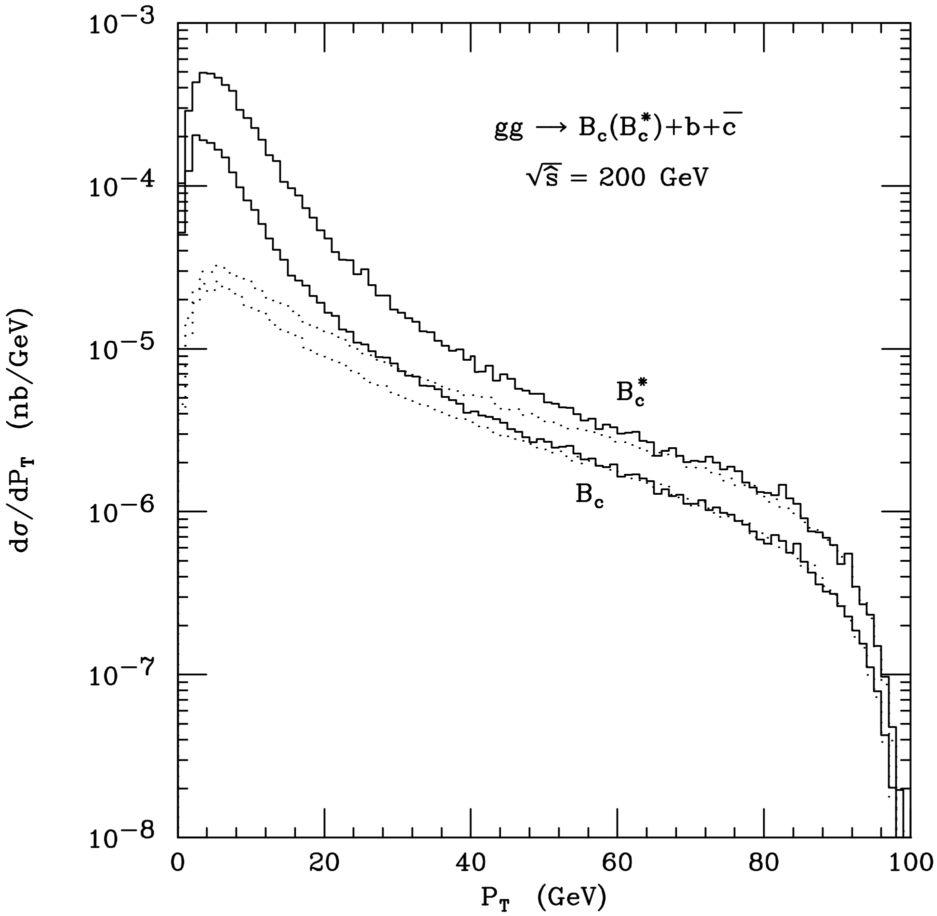

Fig. 2 The P_T distributions of the B_c and B_c^* meson for the subprocess with $\sqrt{\hat{s}} =$ 200 GeV. The solid and the doted lines correspond to the full α_s^4 calculation and the fragmentation approximation, respectively.

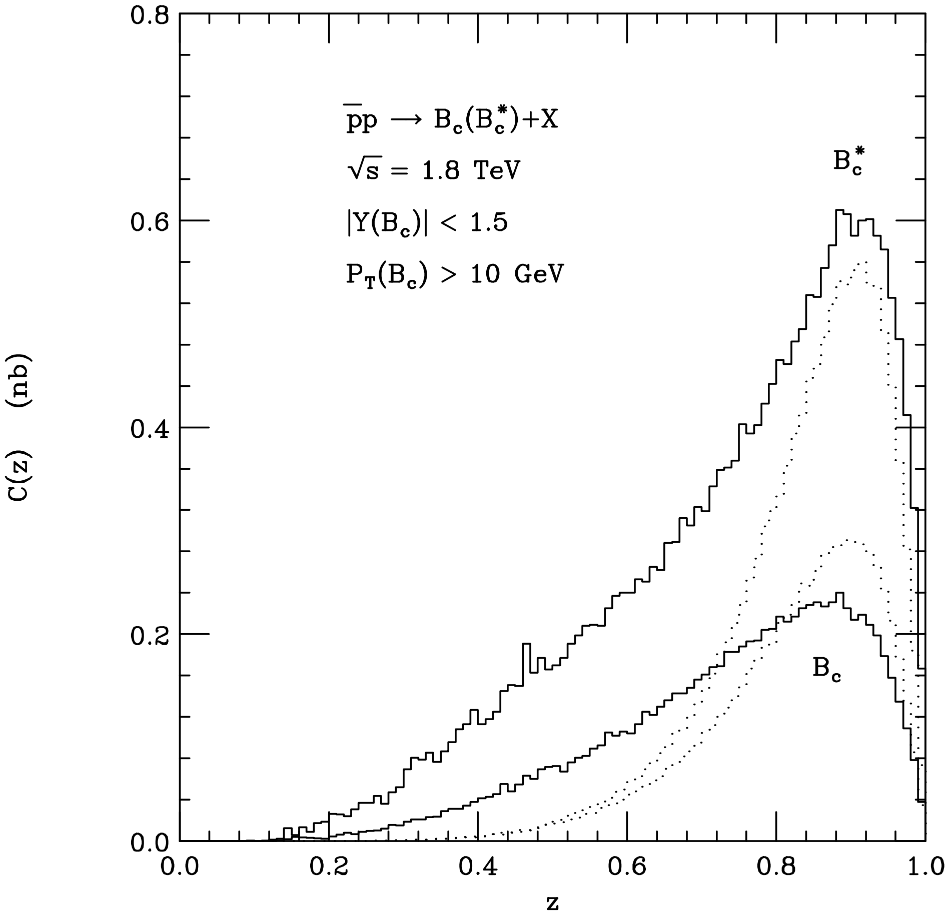

Fig. 3 The z distributions $C(z)$ of the B_c and B_c^* at the Tevatron energy $\sqrt{s} = 1.8$ TeV. The solid lines are the full α_s^4 calculation and the doted lines are the fragmentation approximation with the cut $P_T > 10$ GeV

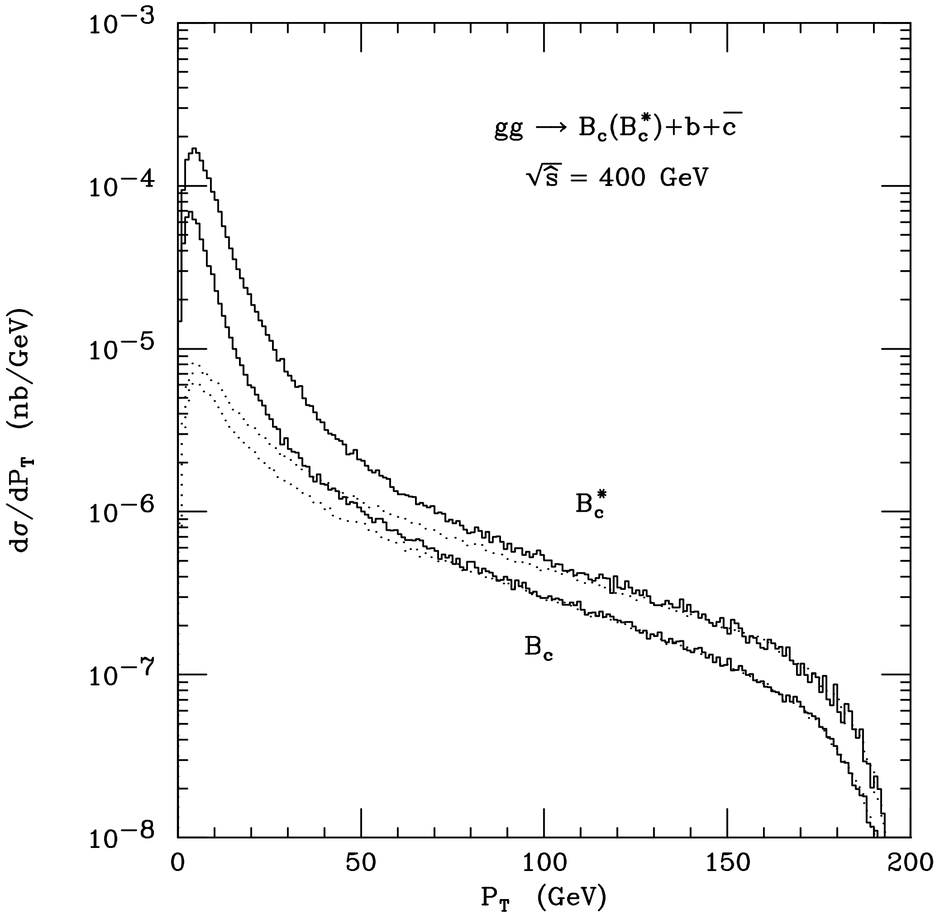

Fig. 4 The P_T distributions of the B_c and B_c^* meson for the subprocess with $\sqrt{\hat{s}} =$ 400 GeV. The solid and the doted lines correspond to the full α_s^4 calculation and the fragmentation approximation, respectively.